Surface and TOA Cloud Forcing from the MLS IWC Product

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Cloud Forcing Intro

- Clouds substantially impact on SW and LW radiative budget
  - Substantial disagreement in cloud forcing (CF) in climate change scenarios
  - Current understanding of UT cloud processes produces disagreements in vertical structure
- CF, if properly used, can diagnose the effect of clouds on climate sensitivity (Soden et al, 2004)
- What can the MLS IWC profiles tell us about the ice cloud contribution to cloud forcing?
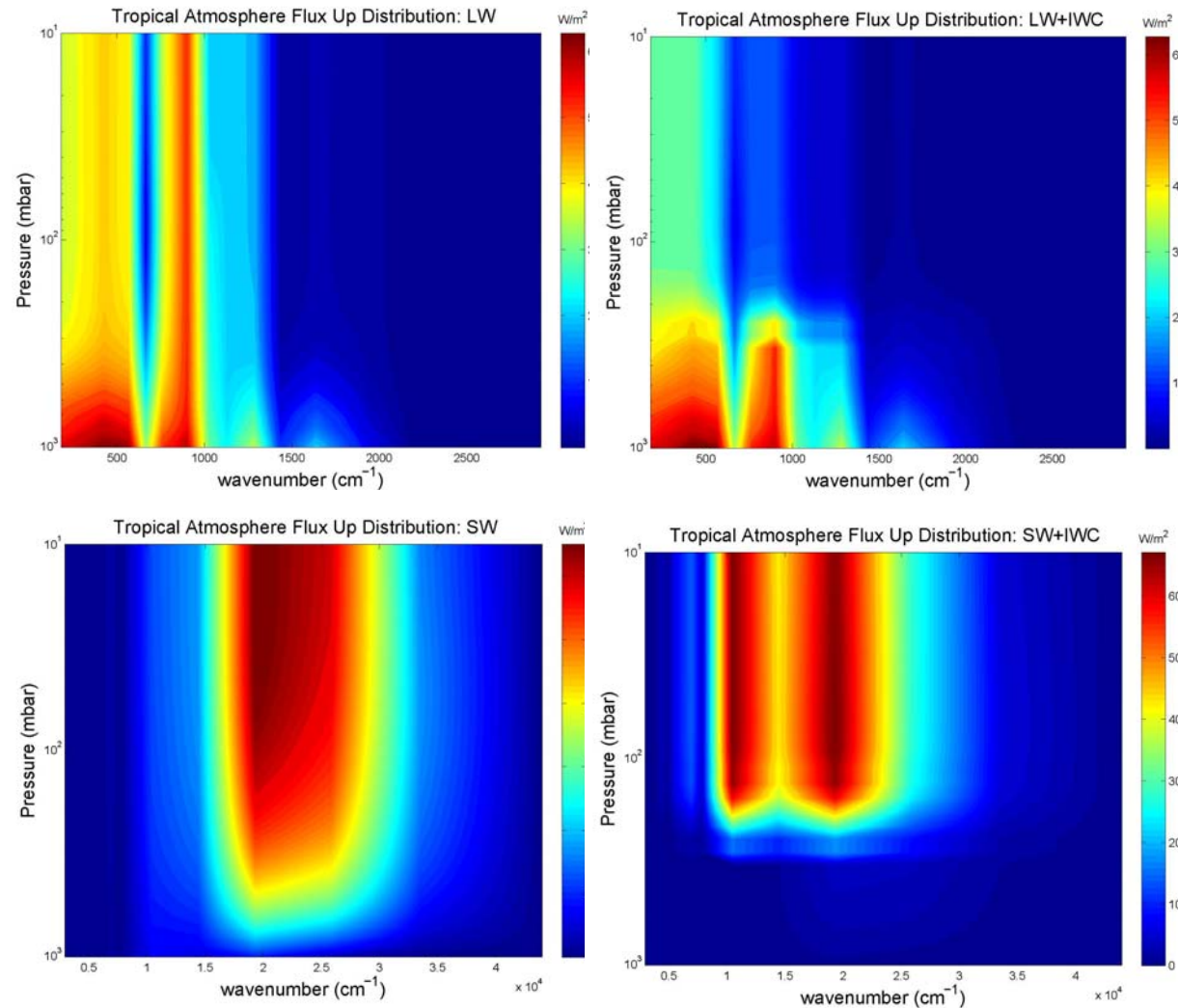 - What lessons can be learned for application to CloudSat cloud forcing studies?
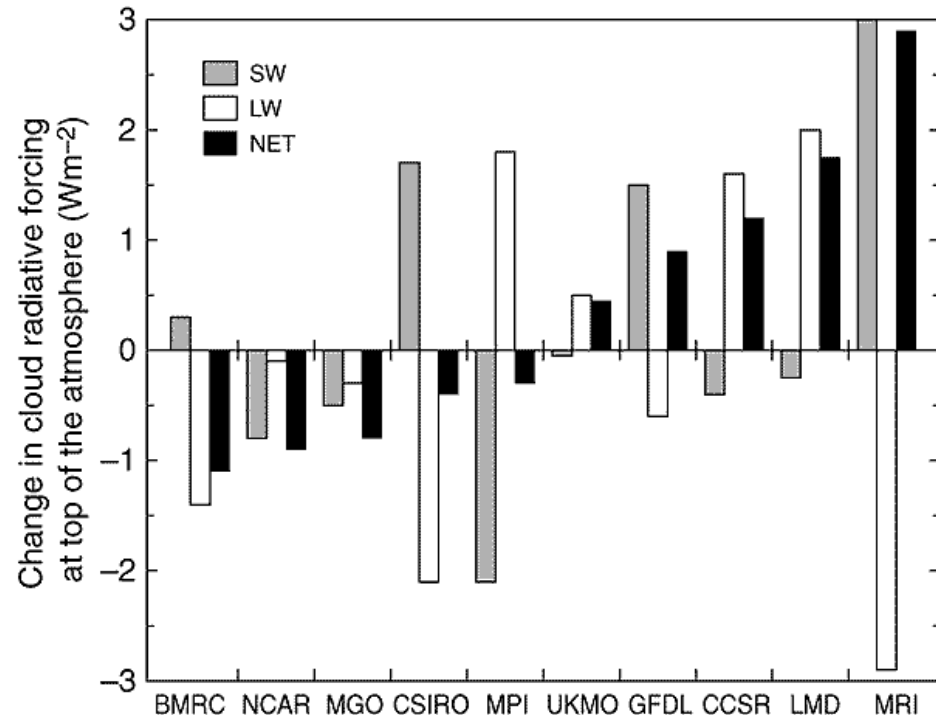
ΔTOA CRF from 2 x CO_2 for several GCM results Le Treut and McAveney, 2000

CF Calculation Basics

- Fast Correlated-K methods utilized
- RRTM_LW :
  - Fluxes: ±1.0 W/m^2 relative to LBLRTM
  - Liquid, ice water clouds
- RRTM_SW :
  - Fluxes: ±1.0 W/m^2 direct, ±2.0 W/m^2 diffuse
  - DISORT: (4-stream w/δ-M scaling)
  - Liquid, ice clouds + aerosols
- Fu-Liou:
  - Shortwave flux from 2-stream
- Our calculation of CF:
 - SW CF – LW CF > 0 → cooling
  - SW CF – LW CF < 0 → heating

$$CF_{SFC}^{TOA} = F\_TOT_{SFC}^{TOA} - F\_CLR_{SFC}^{TOA}$$

Tropical Atmosphere Flux Up Distribution: LW

Tropical Atmosphere Flux Up Distribution: LW+IWC

Tropical Atmosphere Flux Up Distribution: SW

Tropical Atmosphere Flux Up Distribution: SW+IWC

➤ Correlated-K Programs

CF Calculation Considerations

JPL

- Parameters relevant to cloud forcing calculations
  - Cloud water path
  - Effective particle diameter
  - Habit distribution (for SW)
  - Cloud fraction, overlap (for SW)
  - $T(z)$, $H_2O(z)$, $O_3(z)$
  - Appropriate spatial, temporal averaging
- Cloud water path and D_e are semi-independent quantities wrt remote sensing
- Cloud overlap approximation for non-unity horizontal grid cloud fraction
  - Ad hoc schemes for estimating effective between-layer cloud fraction
  - Morcrette et al. 2000: COA important
  - Stephens et al. 2004: COA unimportant
  - What to do about large MLS IWC product grid boxes?
- Temporal averaging
  - For MLS, global coverage requires analysis at monthly time scales.
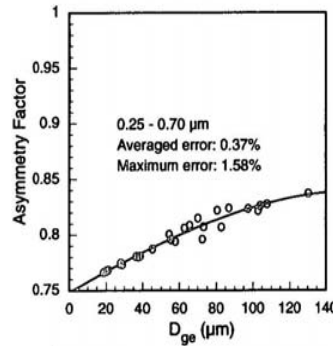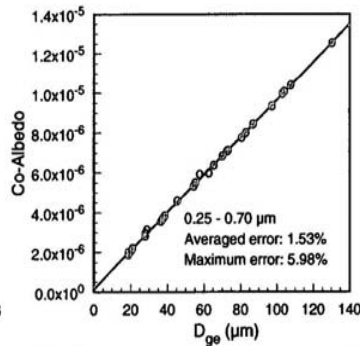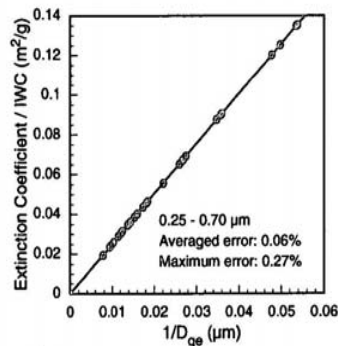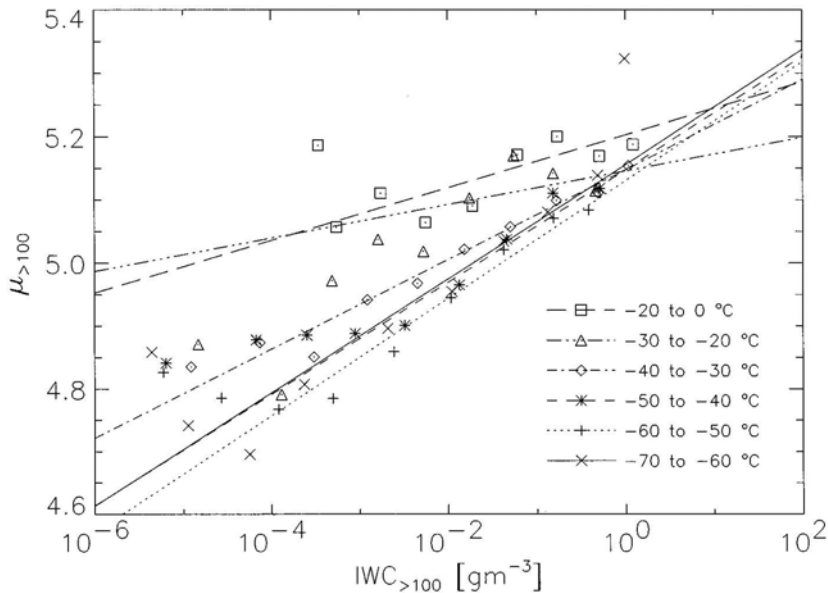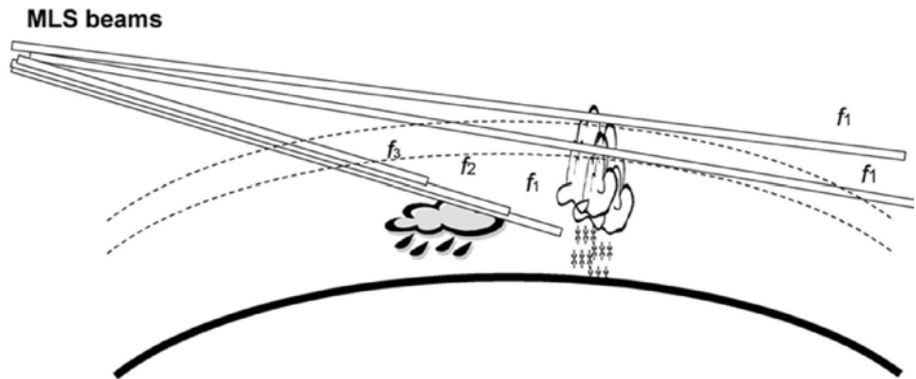
Fu et al, 1996

Morcrette et al, 2000

CF Calculation Complications

2006 Aura STM
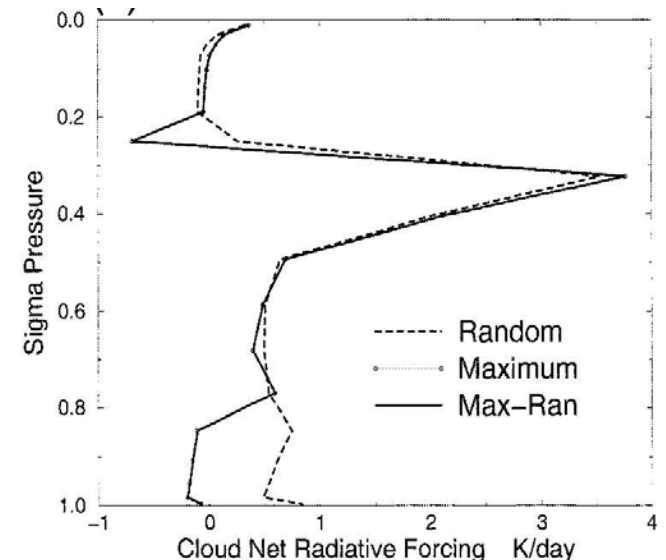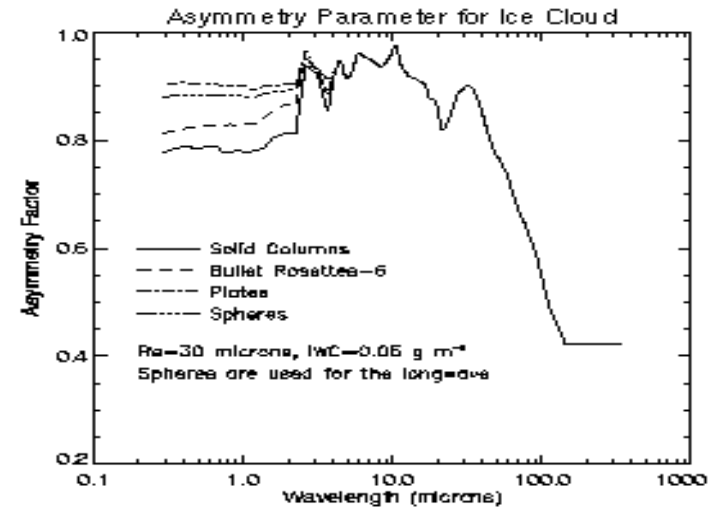
MLS IWC Retrievals

- 200 x 7 x 3 km (along-track, cross-track, vertical)
- 118, 190, **240**, 640, and 2523 GHz frequencies utilized in retrieval
  - <215 hPa, robust retrieval at 240 GHz
- Sequential nonlinear optimal estimation retrieval
  - T, gas profiles first → clear-sky spectra
  - Clear-sky – measurement → cloud-induced radiance
  - CiR inverted for IWC
- Sensitivity range: 0.4 - 50 mg/m^3
- Size distribution inferred from ambient T profile

from McFarquhar et al, 1997
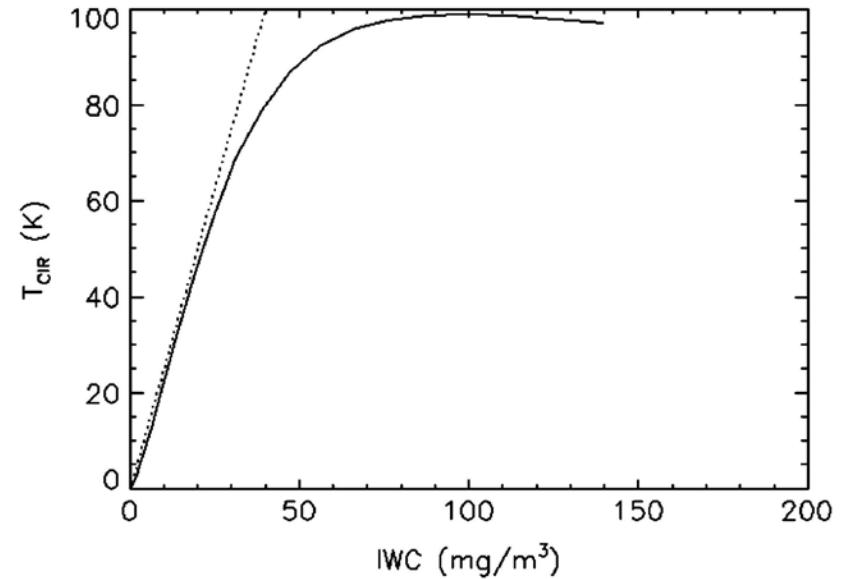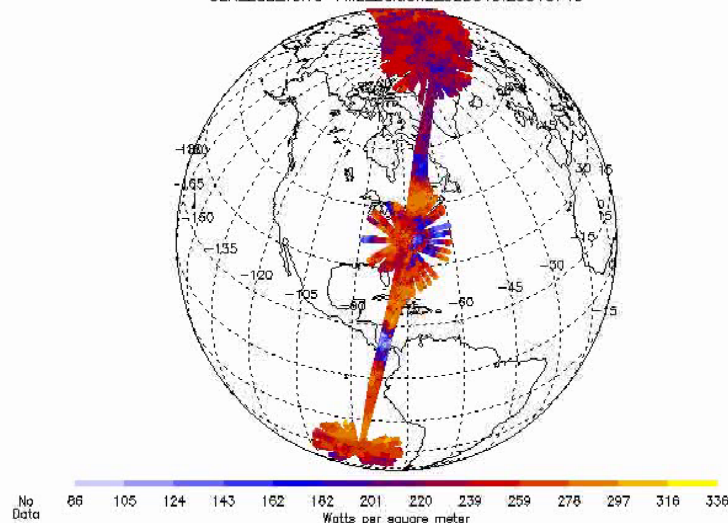
from Wu et al, 2006

Validation Data: CERES

- CERES measures OSR, OLR, and cloud forcing aboard TRMM, TERRA, and AQUA
  - Shortwave (0.3-5.0 µm)
  - Total (0.3-50.0 µm)
  - Window (8-12 µm)
- ES4 products:
  - monthly gridded
  - CERES/model hybrid data
  - 2.5x2.5 resolution
  - ERBE heritage
  - ±6 W/m^2 SW
  - ±1.3 W/m^2 LW
- Combination sets:
  - Multiple CERES instruments
  - MODIS L1B
  - RAP & FAP modes

From http://eosweb.larc.nasa.gov/

CER_ES8_Terra-FM2_Edition2_023019.20010719

Watts per square meter

From http://lposun.larc.nasa.gov

Net Cloud Forcing from CERES Processing
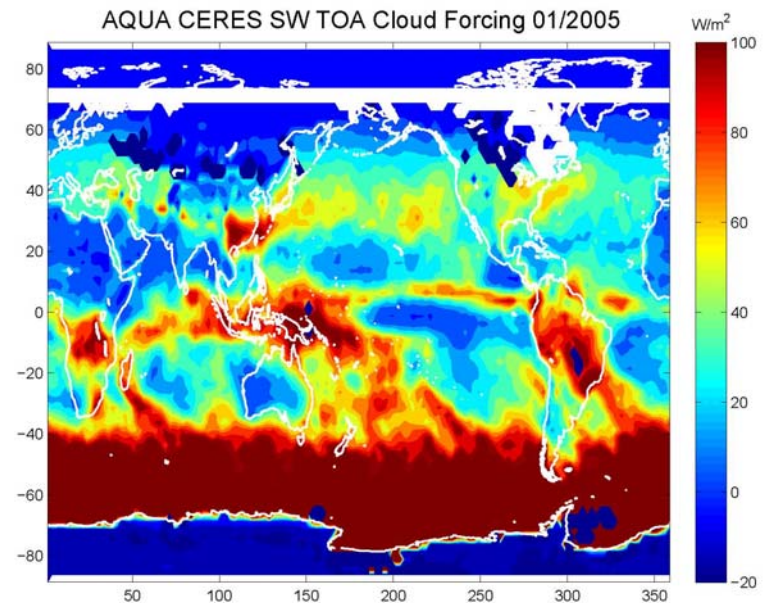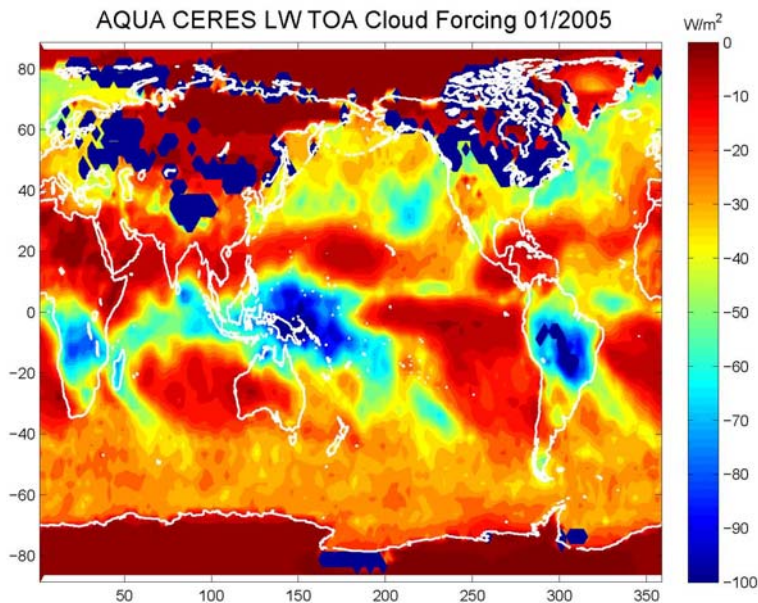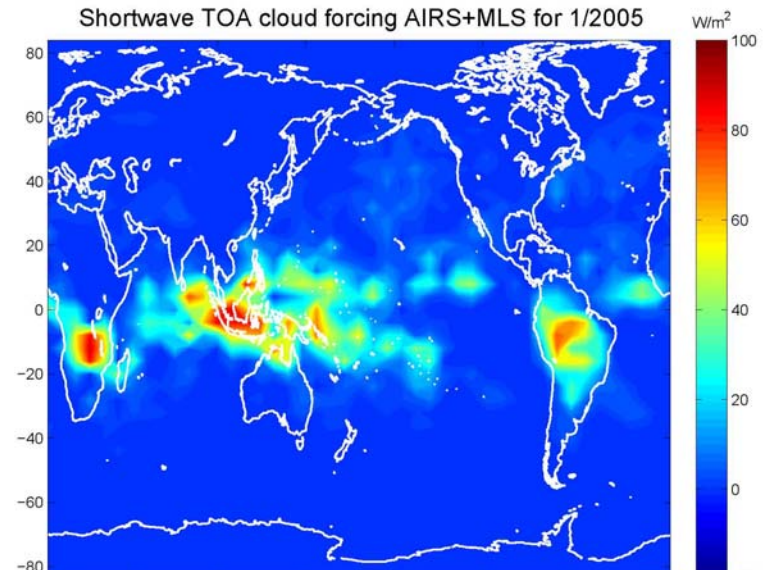AQUA-FM3 January 2005 ES-4
2.5-deg Equal Angle
Processed : 2006/08/16
File : CER_ES4G1_Aqua-FM3_Edition1-CV_024029.200501
Monthly Mean(Hour)

Watts/Meter^2

▶ CERES Products
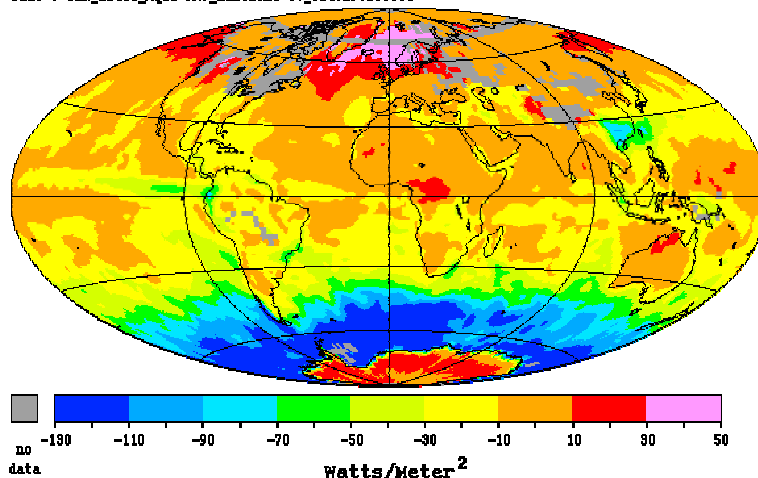
MLS Standard + AIRS L3: 01/2005 vs. CERES

> CERES Intercomparison
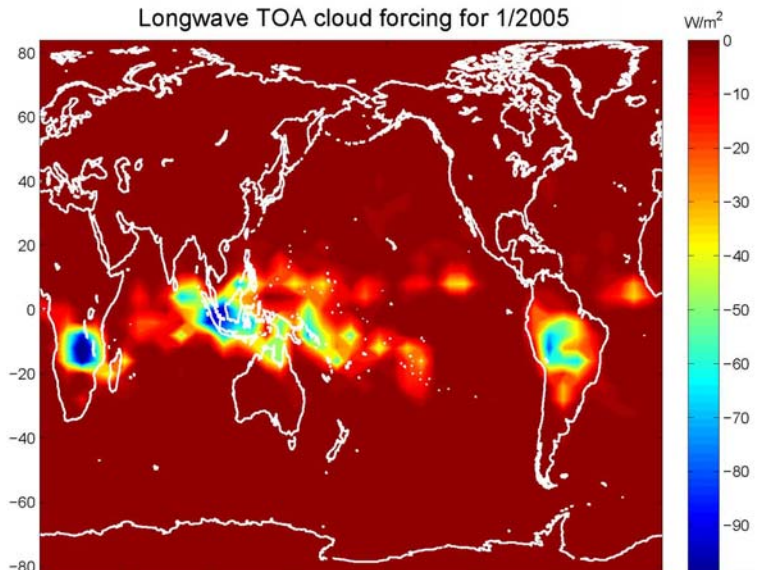
LW Comparison with ECMWF calculations

Longwave TOA cloud forcing for 1/2005
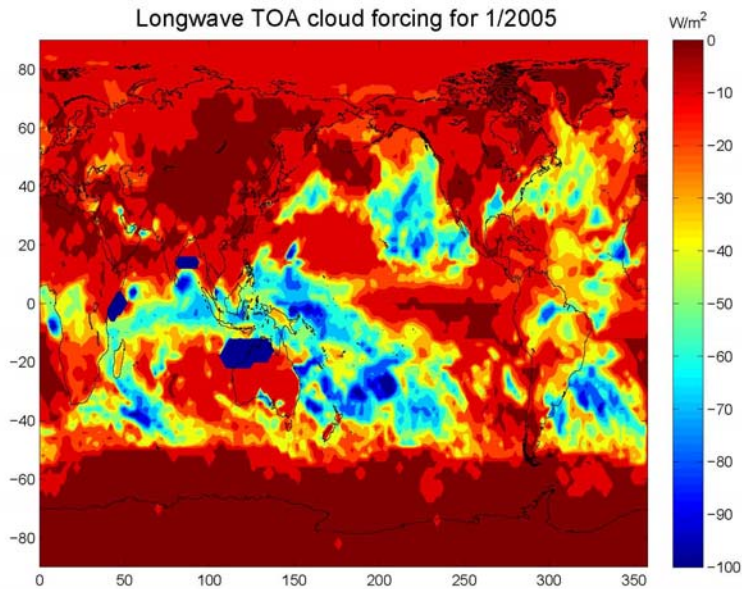
Longwave TOA cloud forcing for 7/2005
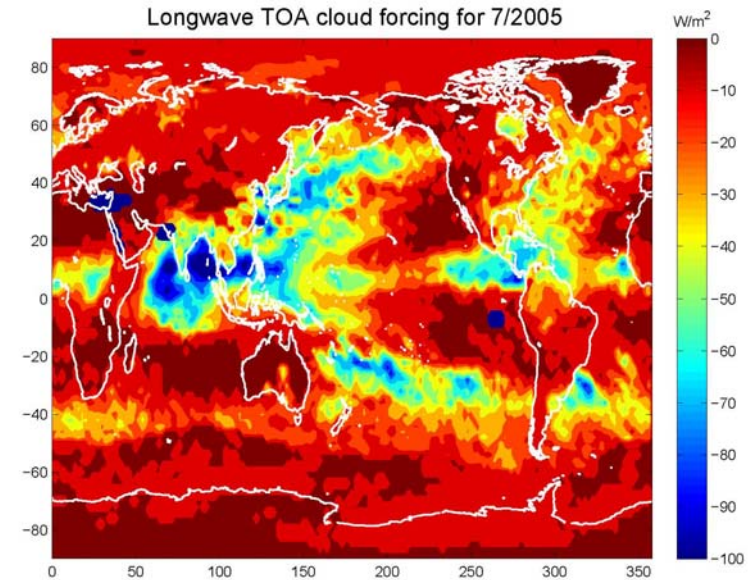
AQUA CERES LW TOA Cloud Forcing 01/2005
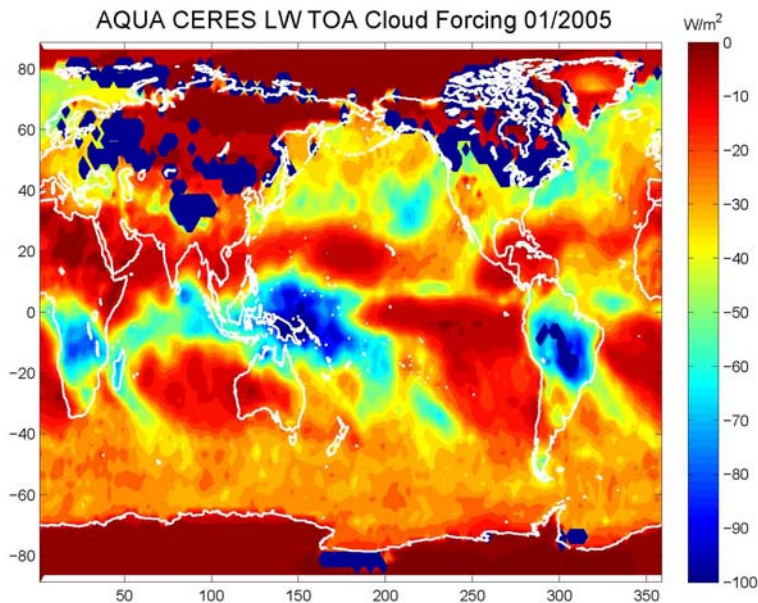
AQUA CERES LW TOA Cloud Forcing 07/2005

➢ ECMWF Intercomparison
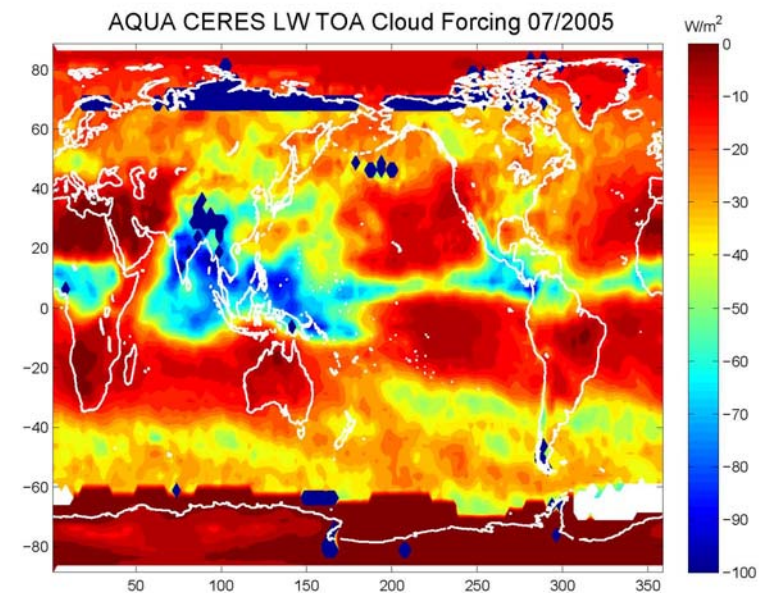
Validation Data: BSRN data

- SKYRAD:
  - Diffuse, Direct SW Irradiance
  - Downwelling LW Irradiance
- State-of-the-art instrument calibration validates cloud forcing calculations and satellite surface flux products
- Continuous sampling facilitates allows for validation of CF forcing calculation assumptions
- ARSCL active sounding information

SKYRAD from www.arm.gov

Map of surface stations from CAVE
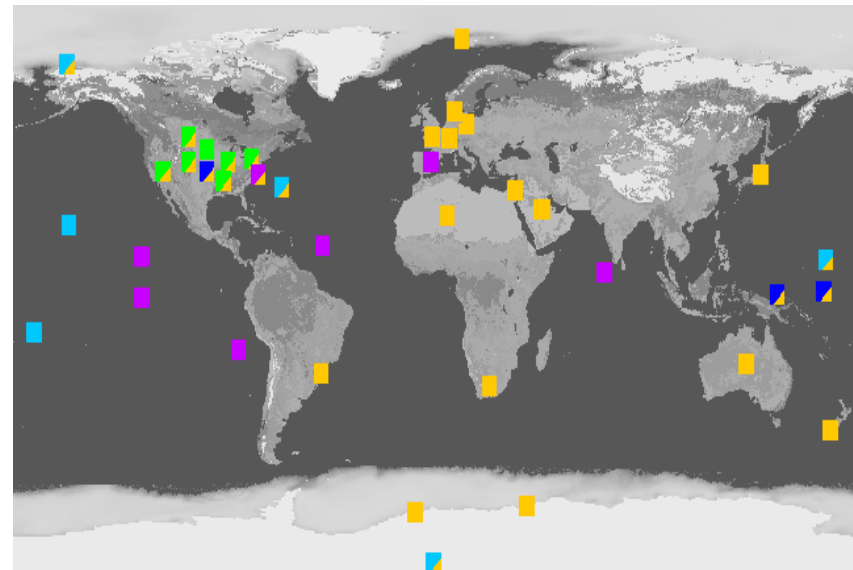
CERES surface flux prediction skill

from http://www-cave.larc.nasa.gov

➢ Surface Site Intercomparison
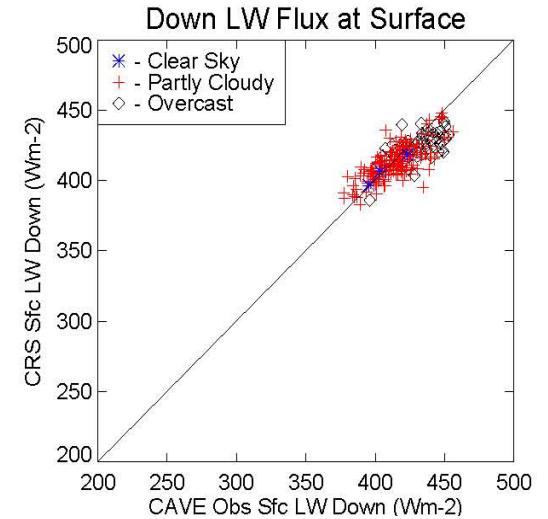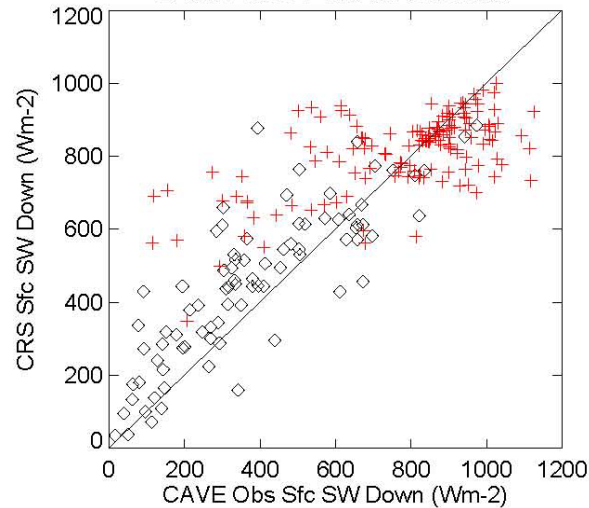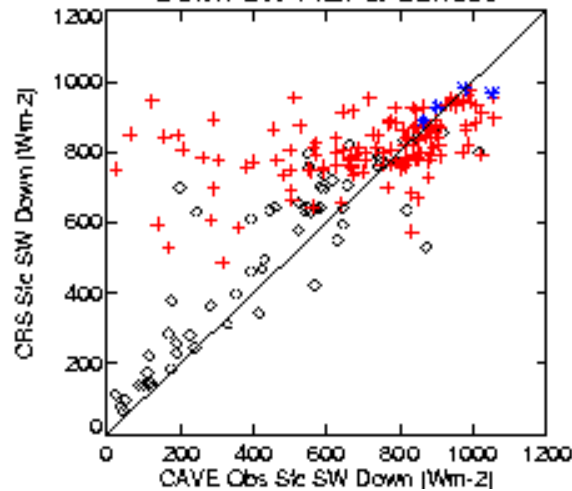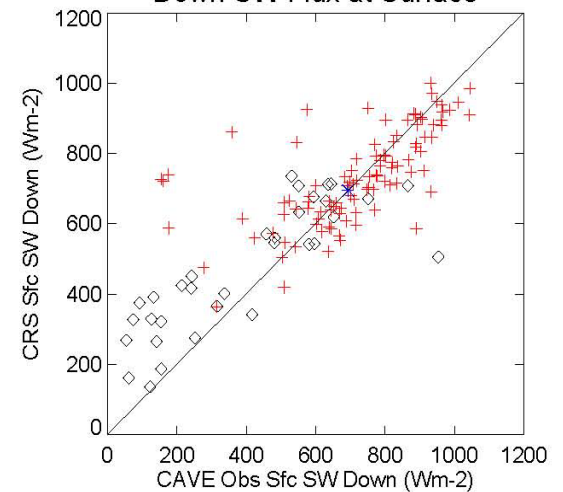
What about CloudSat (+ Calipso)?

- CLOUDSAT
  - Radar activated 06/02/06
  - Operational product specs:
    TOA, SRF flux ±10 W/m^2 instantaneously
  - L2 ATBD:
    - Liquid D_e = 20 μm Ice D_e = 60 μm
    - Will utilize Aqua MODIS to constrain cloud microphysical property parameters
  - Deriving unbiased global cloud forcing maps from Cloudsat is non-trivial
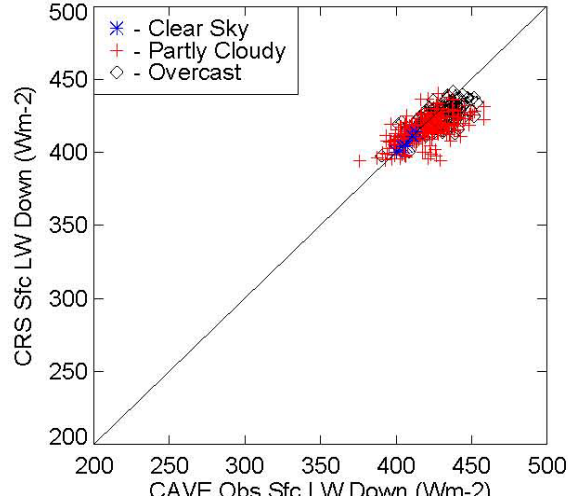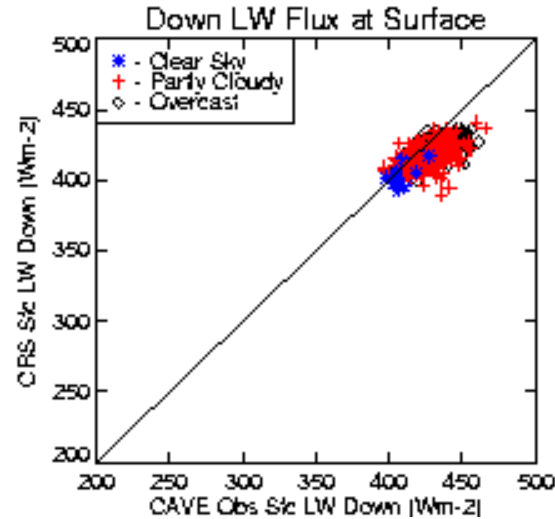 - MLS still provides more global description of UT ice clouds than active sounders
- Ground-based validation more important than ever to interpret cloud forcing from liquid and ice clouds.

AIRS Level-1B Quick Browse Image
11.08 μm Brightness Temperature   Sep 06, 2006 04:41:25 UTC   Granule 047

2006 Sep 6 (249) 03:50:51 UTC | 1A-AUX | Granule 1905   18   Time 04:48:16 04:45:05 | Lat 28.6 17.1 | Lon 129.4 132.1   CIRA CloudSat DPC
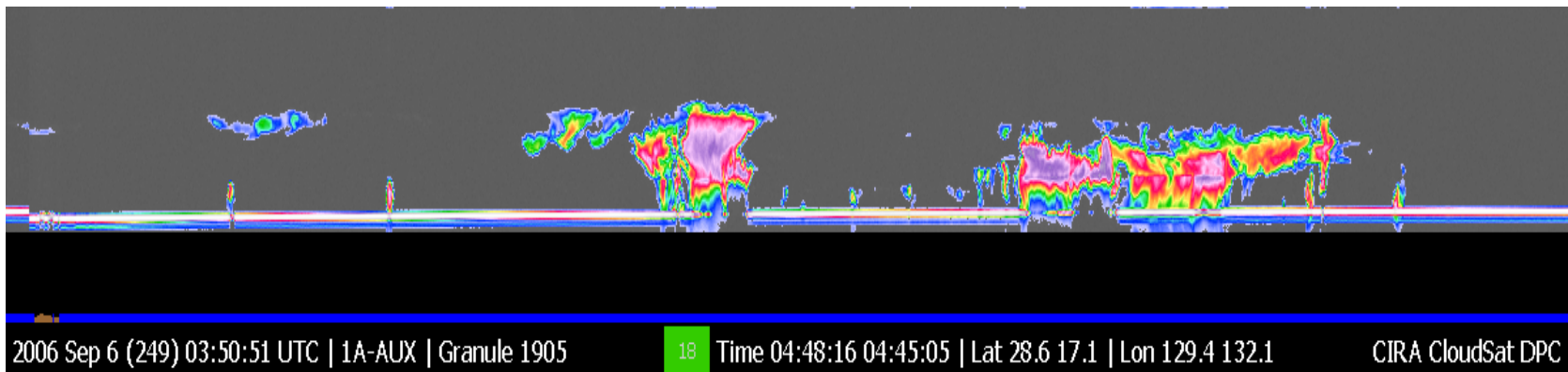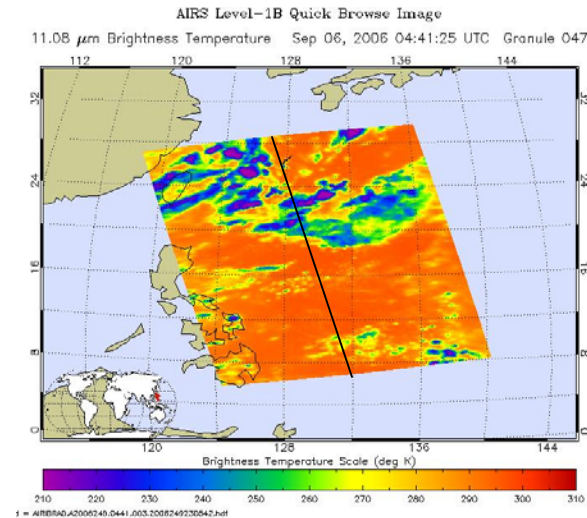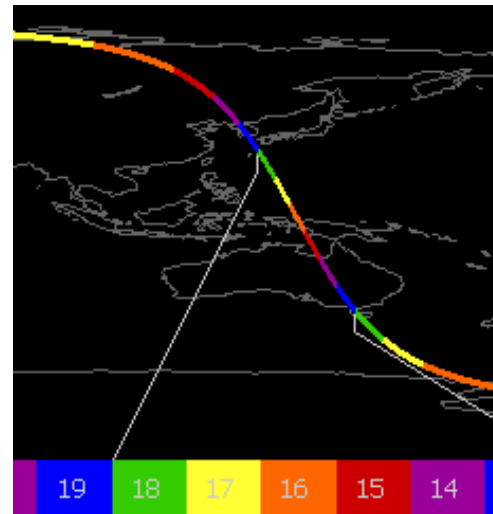
Cloudsat's quicklook at granule 01905, 9/6/06
(from http://cloudsat.atmos.colostate.edu)

Conclusions

- Cloud forcing from MLS requires several assumptions:
  - Cloud particle size
  - Cloud overlap
  - Unbiased temporal averaging
- As compared to CERES Aqua ES-4 product
  - CF from MLS IWC spatial pattern agreement in tropics
  - ECMWF IWC shows greater % of total CF
- Continuous surface site data indicate that:
  - CERES LW surface forcing product robust
  - CERES SW surface forcing product robust only in clear-sky scenarios
- Challenge for utilization of CERES, MLS (and Cloudsat + Calipso): ascription of cloud forcing to ice clouds

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  - Yuk Yung's IR Group
  - NASA ESSF Program

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